TABLE 3. AVERAGE OPERATING COSTS FOR MAJOR OPERATING COST CATEGORIES

Operating cost category	Year									
	1	2	3	4	5	6	7	8	9	10
Support services	$1,126,622	$1,198,861	$1,474,482	$1,560,884	$1,837,836	$2,031,880	$2,268,728	$2,437,329	$2,705,626	$3,127,558
Acquisition	981,998	1,007,698	978,196	1,062,491	1,231,310	1,289,012	1,537,034	1,770,871	1,990,661	2,356,385
Treatment	539,946	577,796	617,713	630,019	701,651	783,581	1,013,585	913,933	998,003	1,212,659
Power and pumping	789,402	830,034	922,020	870,937	933,141	955,478	1,042,051	1,172,427	1,294,861	1,805,530
Transmission and distribution	890,750	927,939	978,982	1,044,549	1,108,421	1,213,655	1,320,415	1,439,312	1,548,570	1,541,550

TABLE 4. AVERAGE UNIT COSTS FOR MAJOR OPERATING COST CATEGORIES
($/mil gal metered consumption

Operating cost category	Year									
	1	2	3	4	5	6	7	8	9	10
Support services	$55.29	$54.6	$62.51	$61.89	$71.66	$76.19	$79.35	$83.49	$91.72	$89.98
Acquisition	48.27	45.91	41.46	42.22	48.08	48.20	53.75	60.69	67.42	67.43
Treatment	26.58	26.27	26.10	25.0	27.44	29.39	35.41	29.63	33.85	35.01
Power and pumping	38.70	37.85	38.94	34.43	36.51	35.74	36.42	40.29	43.98	52.08
Transmission and distribution	43.81	42.19	41.46	41.40	43.32	45.38	46.21	49.30	52.37	44.27

TABLE 5. AVERAGE OPERATING COST CATEGORIES AS PERCENT OF TOTAL OPERATING COST

Operating cost category	Year									
	1	2	3	4	5	6	7	8	9	10
Support services	26.0	26.4	29.7	30.2	31.6	32.4	31.6	31.5	31.7	31.1
Acquisition	22.7	22.2	19.7	20.6	21.2	20.5	21.4	22.9	23.3	23.5
Treatment	12.5	12.7	12.4	12.2	12.1	12.5	14.1	11.8	11.7	12.1
Power and pumping	18.2	18.3	18.5	16.8	16.1	15.2	14.5	15.2	15.2	18.0
Transmission and distribution	20.6	20.4	19.7	20.2	19.1	19.3	18.4	18.6	18.1	15.3

TABLE 6. AVERAGE OPERATING AND CAPITAL COSTS

Item	Year									
	1	2	3	4	5	6	7	8	9	10
Operating cost ($)	4,074,911	4,272,278	4,579,474	5,030,824	5,830,681	6,285,280	6,934,452	7,598,149	8,431,726	9,262,730
Depreciation ($)	1,241,563	1,296,702	1,430,217	1,547,238	1,604,659	1,661,276	1,693,273	1,828,003	1.904,825	2,145,428
Interest ($)	996,955	920,622	948,614	1,286,566	1,267,062	1,428,970	1,411,346	1,488,971	1,707,623	1,848,256
Total cost ($)	6,313,429	6,490,102	6,958,305	7,864,628	8,702,402	9,375,526	10,039,071	10,915,123	12,044,174	13,256,414
Unit cost ($/mil gal)	332.88	322.45	328.39	327.39	340.26	354.23	370.57	387.88	425.93	416.74

TABLE 7. OPERATING AND CAPITAL EXPENSE RATIOS

Item	Year									
	1	2	3	4	5	6	7	8	9	10
Operating cost ($)	4,074,911	4,272,278	4,579,474	5,030,824	5,830,681	6,285,280	6,934,452	7,593,149	8,431,726	9,262,730
Capital cost ($)	2,238,518	2,217,324	2,378,831	2,833,804	2,871,721	3,090,246	3,104,619	3,316,924	3,612,448	3,993,684
Interest ($)	996,955	920,622	948,614	1,286,566	1,267,062	1,428,970	1,411,346	1,488,971	1,707,623	1,848,256
Total cost ($)	6,313,429	6,490,102	6,958,305	7,864,628	8,702,402	9,375,526	10,039,071	10,915,123	12,044,174	13,256,414
Operating cost as % of total	64.5	65.8	69.4	64.0	67.0	67.0	69.1	69.6	70.0	69.9
Capital cost as % of total	35.5	34.2	30.6	36.0	33.0	33.0	30.9	30.4	30.0	30.1

TABLE 8. MANPOWER COSTS

Item	Years									
	1	2	3	4	5	6	7	8	9	10
Total payroll ($)	1,713,806	1,825,217	2,006,525	2,237,453	2,525,527	2,724,751	3,040,661	3,392,529	3,665,588	3,857,361
Total hours for O&M Payroll	659,156	683,602	716,616	743,340	756,145	754,778	787,736	794,503	816,389	813,789
Metered consumption (mil gal)	22,193	23,930	24,619	25,864	27,456	28,736	28,904	30,159	29,857	34,169
Total payroll/metered consumption ($/mil gal)	77.22	76.27	81.50	86.51	91.98	94.82	105.28	112.49	122.77	112.89
Total hours/metered consumption (hr/mil gal)	33.75	32.50	30.42	29.85	31.17	29.70	30.32	29.83	30.50	28.32
Average cost/man-hour ($)	2.60	2.67	2.80	3.01	3.34	3.61	3.86	4.27	4.49	4.74
Capital/labor cost ratio	1.31	1.21	1.18	1.27	1.14	1.13	1.02	0.98	0.99	1.04

SECTION 5

CINCINNATI WATER WORKS

The City of Cincinnati is located in Hamilton County in southwestern Ohio. Based on the 1970 census, the city has a population of 452,524, and the county, 924,018. During the past few years, both the city and the county have been declining in population. Some system facts are shown in Table 9.

WATER SUPPLY SERVICE AREA

The Cincinnati Water Works, owned and operated by the City of Cincinnati, is a self-sustaining public utility. It is metropolitan both in nature and scope since water is served to areas outside the city limits.

In 1955, the City of Cincinnati and Hamilton County joined in a contract that stipulated that the Cincinnati Water Works would serve approximately 80% of Hamilton County for a period of 30 years (Figure 3). In 1961, the Water Works contracted to serve a portion of Butler County, and in 1967 a portion of Warren County was added. A number of communities maintain their own systems but are surrounded by the Cincinnati Water Works service area. Emergency service is provided to most of them, but as long as their source of supply can be maintained, most of the communities will not change their present status. The distribution area and the facilities used are shown in Figure 4. One city has its own distribution system, but it is served by the Cincinnati Water Works.

The Cincinnati Water Works currently serves over 186,000 accounts through more than 3,785 miles of water mains. It has been expanding at the rate of 3,000 accounts and 35 miles of mains each year. In 1974, the Water Works supplied approximately 840,000 people at a daily rate of 132.9 mil gal (almost 158 gallons/capita/day). The amount of water supplied might be greater except for the large amount of well water available in the area to consumers who wish to develop their own supplies. One private water purveyor supplies approximately 17 MGD for industrial use.

ORGANIZATION

The Cincinnati Water Works serves only as a water utility, but it does collect revenue for the Metropolitan Sewer District. The structure of the organization depicted in Figure 5 is composed of administration, supply, distribution, and commercial divisions.

TABLE 9. CINCINNATI WATER WORKS, BASIC FACTS*

Item	Amount
Population:	
City	452,524
County	924,018
Retail service area	840,000
Area of retail service area (sq miles)	312.73
Number of metered customers	186,000+
Percent metered	100
Source water	100% Surface (river)
Pipe in system (miles)	3,785
Elevation of treatment plant (ft above mean sea level)	532
Elevation of service area (min - max)	500 - 1001
Revenue-producing water (mil gal)	38,104
Treated water (mil gal)	48,627
Maximum day/maximum hour (MGD)	237/231

* 1973 data.

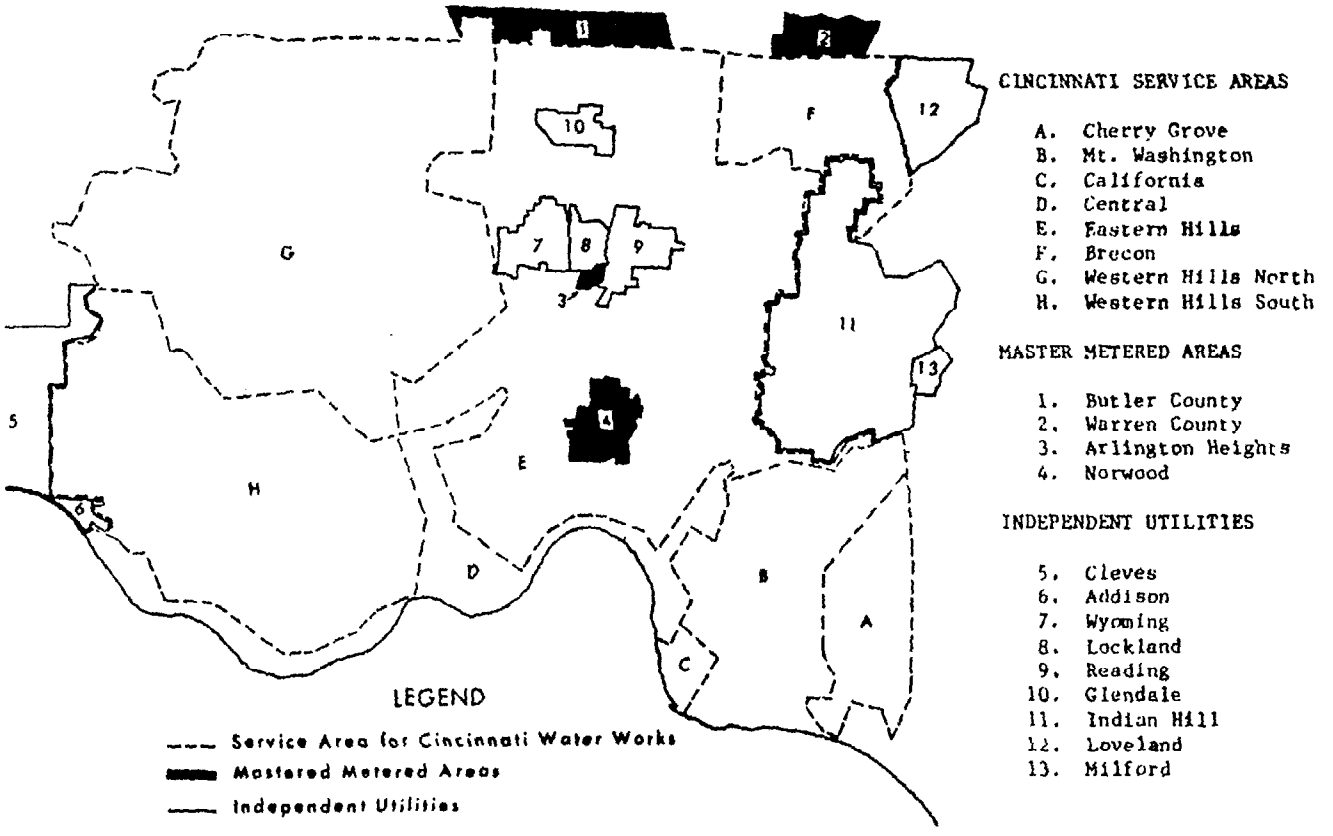

Figure 3. Cincinnati Water Works service area.

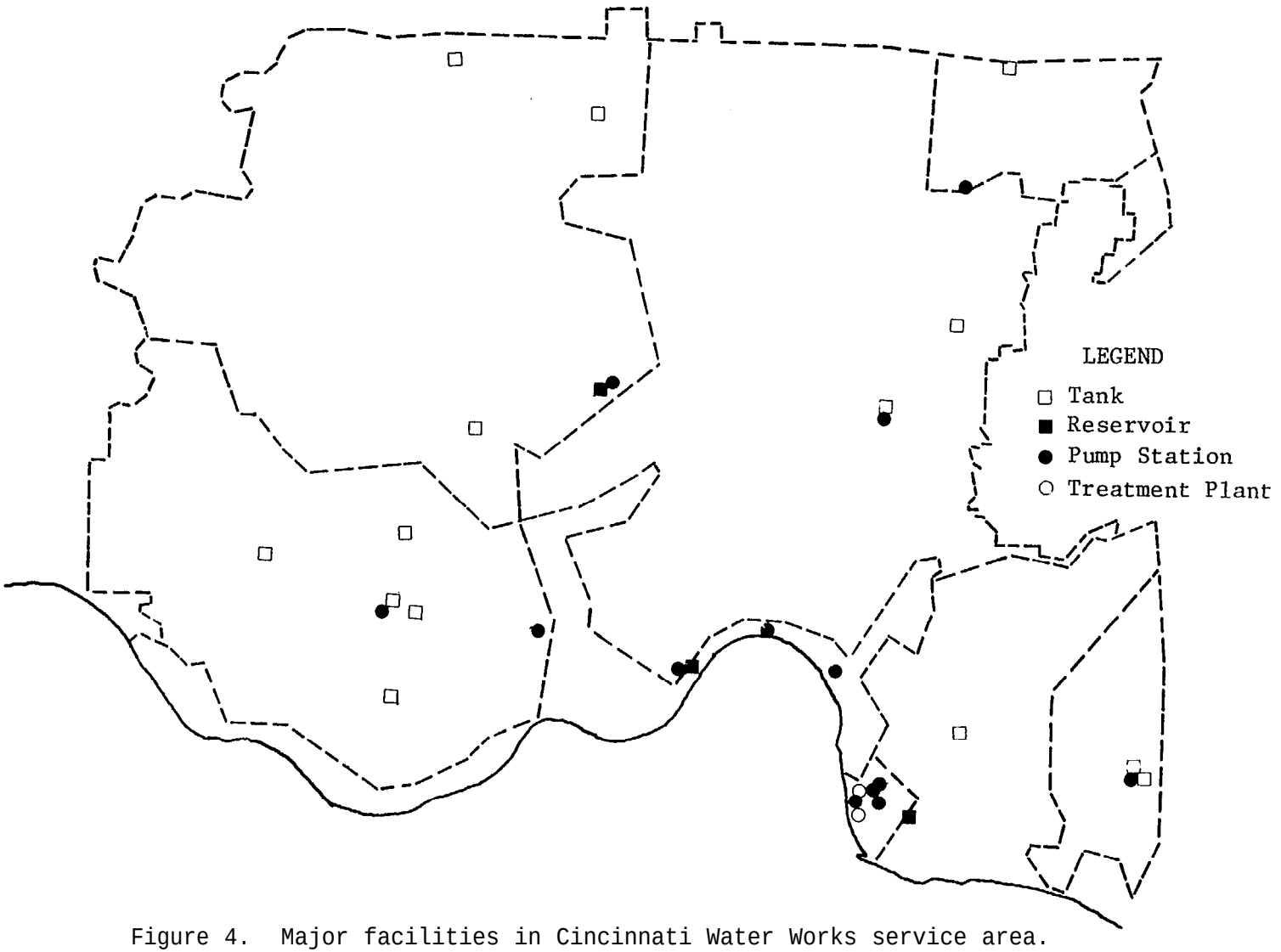

Figure 4. Major facilities in Cincinnati Water Works service area.

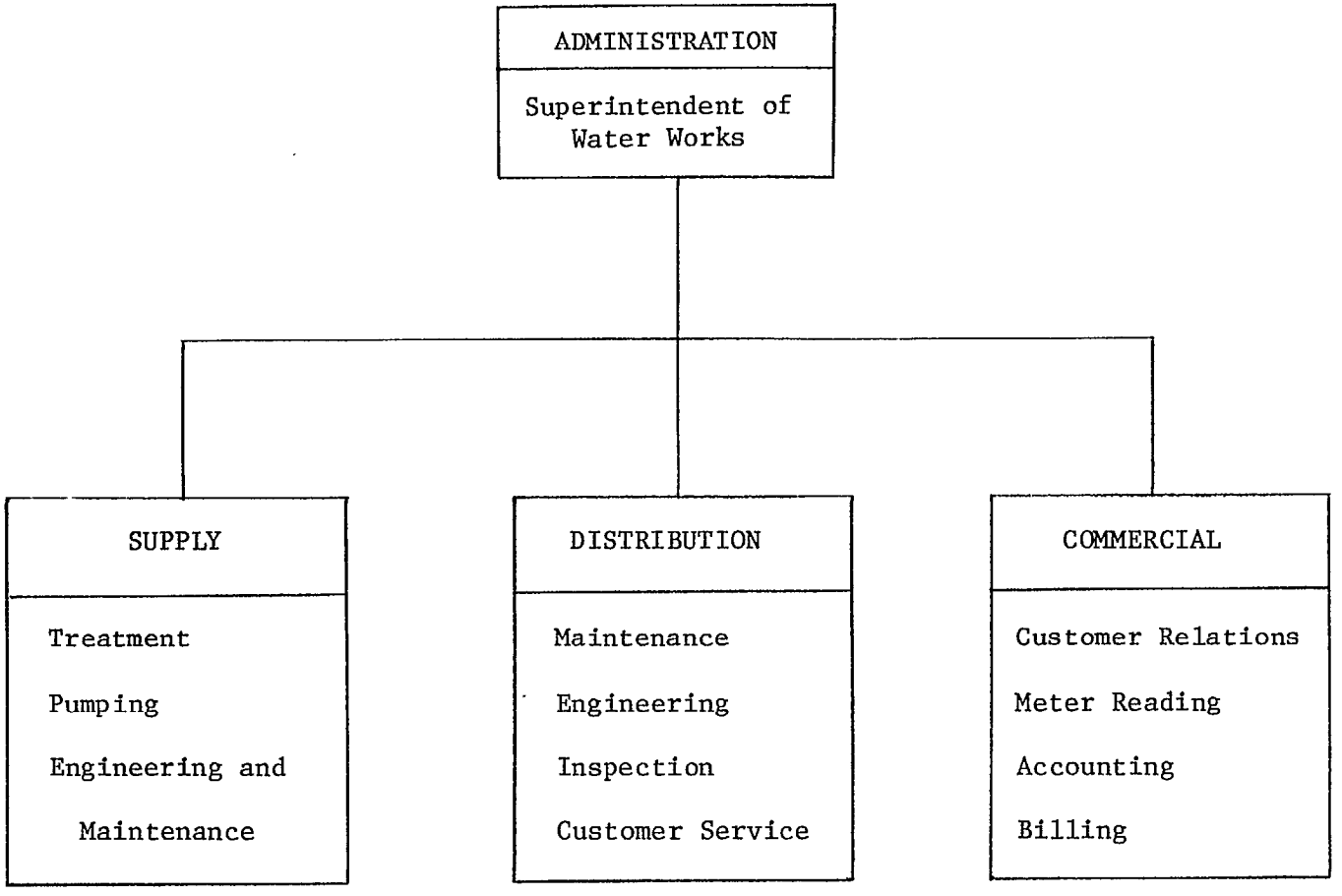

Figure 5. Cincinnati Water Works organizational chart.

The administrative division plans all system improvements, analyzes the adequacy of the system, develops the rate structure, and coordinates long-range plan development.

The supply division handles treatment, pumping operation, and some engineering and maintenance, especially in connection with new facilities or replacements.

The distribution division involves engineering, inspection, and maintenance of tanks, reservoirs, and equipment. The customer service section maintains and replaces meters for each account.

Finally, the commercial division controls the accounts receivable, which includes meter reading, accounting, billing, and customer relations.

ACQUISITION

Raw water comes from an intake pier located in Kentucky on the south side of the Ohio River. Water obtained through this pier is pumped to two nearby settling basins having a combined capacity of 372 mil gal. As water flows to the settling basins, chlorine, alum, and activated carbon may be added as needed. From the settling basins, water flows by gravity to the treatment plant.

TREATMENT

All raw water is treated at the complex in California, Ohio, just east of Cincinnati, The treatment plant, built in 1936, contains facilities for chemical treatment, coagulation, and flocculation; 47 filter beds, each with a capacity of 5 MGD; and two clear wells with a combined capacity of 28.3 mil gal for storage of treated water.

In the chemical treatment processes, six chemicals are fed in proportion to the amount of water treated, but the quality of the raw water determines the specific amount of each chemical used. The chemicals used, their purpose, and their order of application are as follows:

1. Chlorine, alum, and activated carbon may be added before pumping to the settling basins. The purpose here is basically taste and odor control as well as control of algae. Alum is also used for coagulation.

2. Lime, ferric sulfate, soda ash (sodium carbonate), and activated carbon are added as water flows from the settling basins through the chemical house to the coagulating basins. Provision exists for necessary chlorine addition. Ferric sulfate and alum are used for coagulation. Lime and soda ash affect the mineral content, and activated carbon is used for taste and odor control.

3. Once 'the water leaves the filter house, it is collected in the clear wells. At this point, chlorine and soda ash can again be added as needed. Figure 6 shows the plan of the Cincinnati treatment plant.

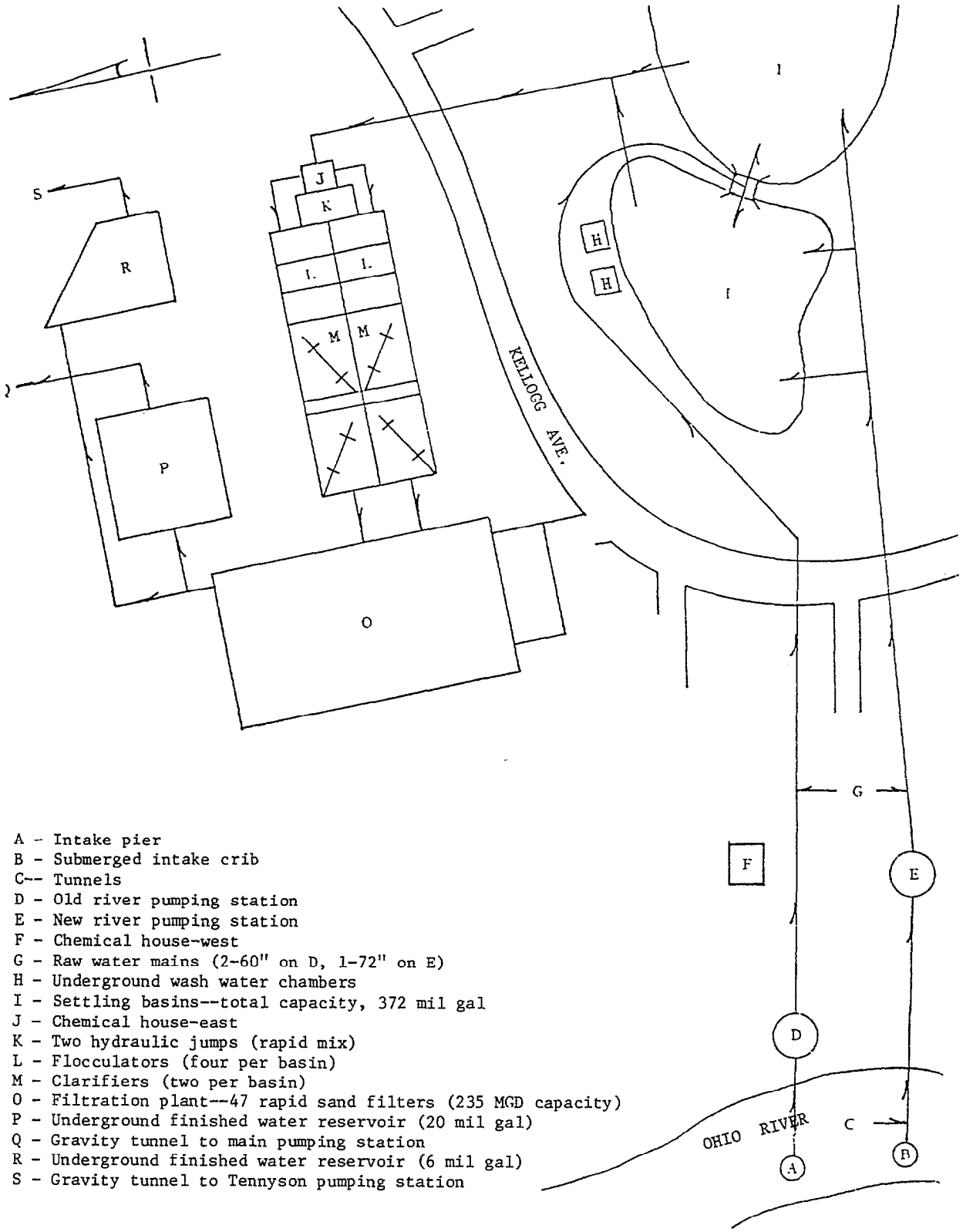

Figure 6. Cincinnati Water Works supply division.

TRANSMISSION AND DISTRIBUTION

The current source of supply is the Ohio River, from which water is pumped to the treatment plant. The plant has a capacity of 235 MGD, and in 1973, it treated an average of 136 MGD. Water is distributed to the east through a series of pumping stations and tanks. To the north and west, water passes through two gravity tunnels and two pump stations and it is then repumped into outlying service areas.

The distribution system consists of approximately 3,785 miles of mains composed of 3- to 60-in. pipe. The two gravity tunnels are 84 and 96 in. in diameter. Figure 7 provides a simplified diagram of the transmission system.

There are 17 storage facilities in the system to provide pressure as well as 152.7 mil gal storage for peak demand periods. There is an elevation difference of about 500 ft between the hilly zones and the treatment plant. Five of the 17 storage facilities are not elevated. They have a combined capacity of 96.6 mil gal. All but the Sutton Road Reservoir have pumping capability to increase pressure in the distribution system. Table 10 lists the water storage facilities in the network.

COST ANALYSIS

Total water pumped by the Cincinnati utility during calendar years 1964 through 1973 as well as metered RPW and water that was accounted for but did not produce revenue are shown in Figure 8. All cost data are based on RPW; for example, purification costs in dollars per million gallons ($/mil gal) are based on RPW and not on the total number of gallons of water pumped by the utility. As Figure 8 shows, the total water pumped exceeded RPW by nearly 13,000 mil gal in 1973.

Table 11 contains the total operating cost for each of the previously mentioned categories. Support services includes all of those operating costs that support but are not directly chargeable to the production of water. Such items as general administration, accounting and collection, and meter reading are included. The subcategory "Other", which includes pensions, workman's compensation, charges by other city departments, and security, shows a sharp increase between 1968 and 1969 as a result of the addition of fulltime guards to the Water Works staff. Purification includes those costs related to operating the laboratory, labor involved in the treatment function, chemicals for purifying the water, and maintenance of the treatment plant. Power and pumping includes costs related to operating labor, maintenance, and power for pumping water throughout the service area. Transmission and distribution includes the operating labor and maintenance costs associated with supplying water to the consumer.

Costs for support services more than doubled between 1964 and 1973. All of the other cost categories increased during this period, but their rates of increase were smaller. Total operating costs increased by about 65%.

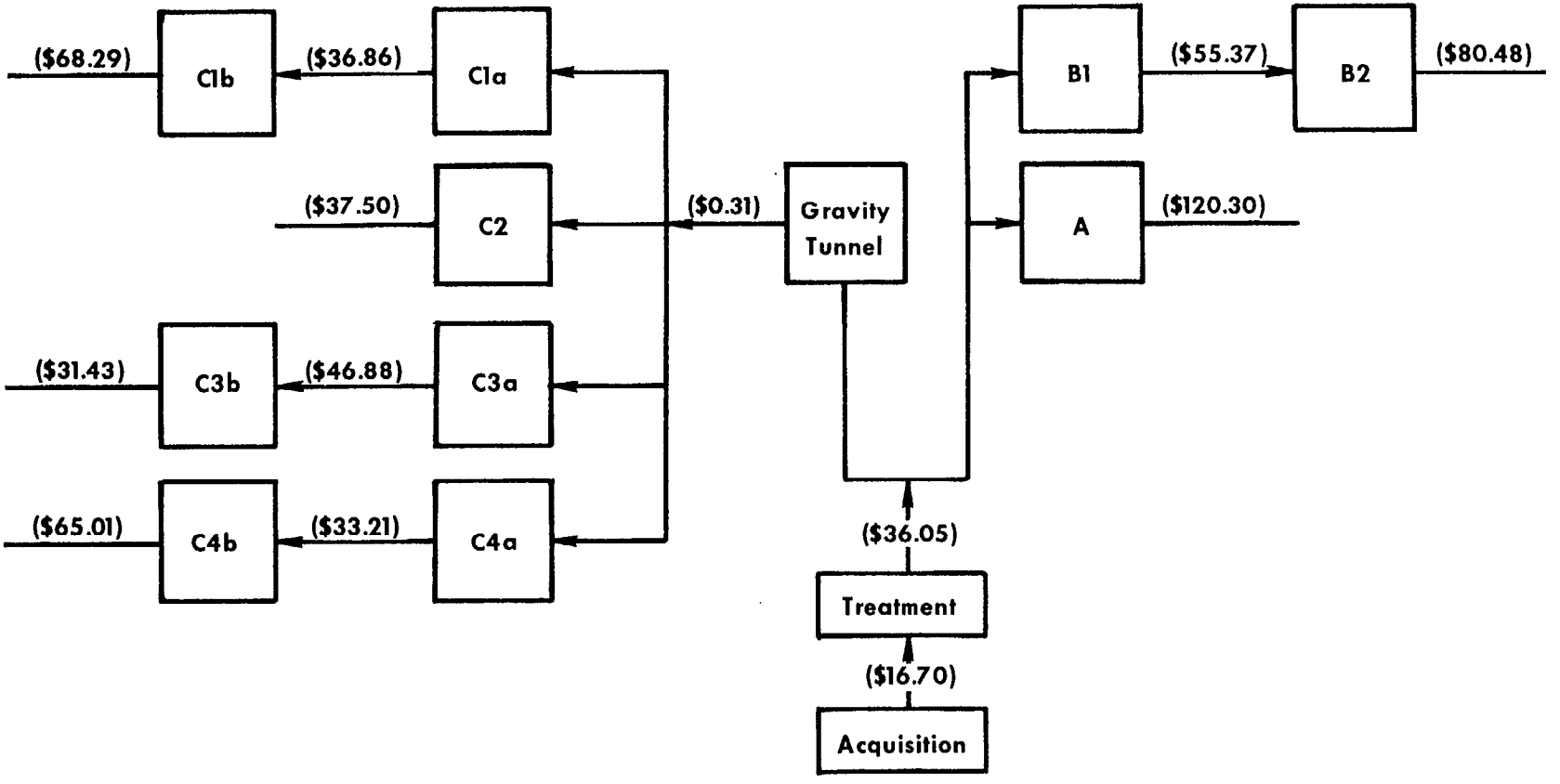

Figure 7. Schematic diagram of treatment plant costs ($/mil gal) in the Cincinnati Water Works system, A, B1, B2, etc. denote service areas. (See Figure 9 for geographic locations.)

TABLE 10. CINCINNATI WATER WORKS STORAGE FACILITIES

Type of storage	Ground elevation (ft)	Overflow elevation (ft)	Capacity (mil gal)
Tank storage:			
Brecon elevated	955	990	1
Cherry Grove elevated	1001	1030	1
Cherry Grove tank	887	950	2
Delhi Hills tank	995	1030	2
Ferguson Road tanks	966	1028	1.4
Greenhills tank	898	950	1.5
Kugler Mill elevated	930	960	1
Mack tank	995	1030	2
Mt. Airy tanks	966	1028	8.5
Mt. Washington tank	808	950	1.2
Pleasant Run elevated	995	1030	2
Wardall elevated	995	1030	2.5

	Elevation bottom (ft)	Elevation top (ft)	Capacity (mil gal)
Ground storage:			
Eden Park Reservoir	643	682	80
Kennedy underground	829	845	6
Summit underground	868	882	4.9
Sutton Road Reservoir	660	683	1.1
Winton Road Reservoir	920	950	34.6
Total capacity	---	---	152.7

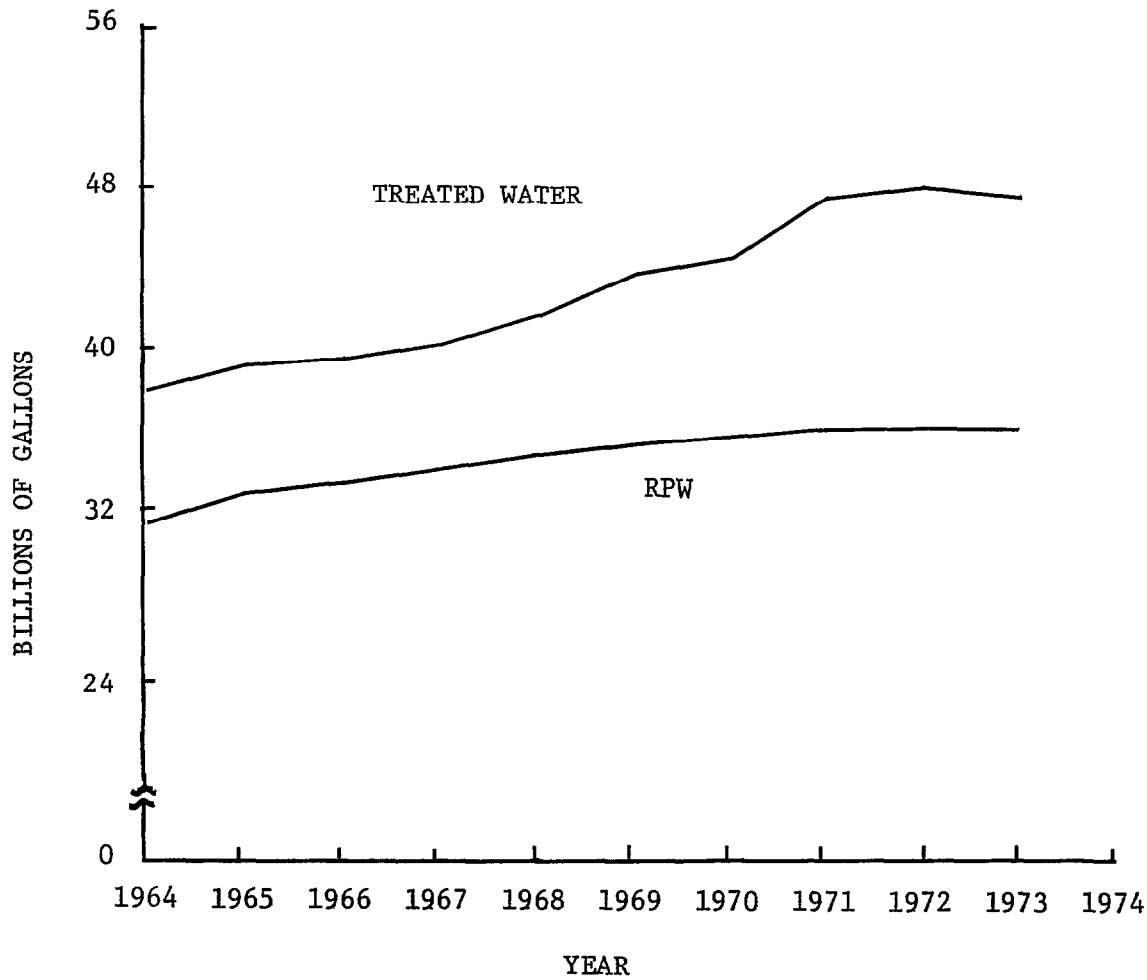

Figure 8. Cincinnati Water Works water flow, 1964 to 1973: treated water versus RPW.

TABLE 11. CINCINNATI WATER WORKS ANNUAL OPERATING COSTS

Category	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Support services:										
Administration	$235,834	$243,870	$250,774	$295,445	$306,583	$336,236	$359,307	$384,356	$465,136	$451,404
Acctg and collection	282,963	278,983	292,656	324,660	395,372	410,427	422,221	480,680	533,285	585,288
Service	225,768	233,539	245,552	249,206	256,748	302,611	300,214	351,596	370,723	407,787
Other	615,177	574,111	624,059	629,284	647,647	1,059,359	999,165	1,155,109	1,264,105	1,321,758
Total support services	1,359,742	1,330,503	1,413,041	1,498,595	1,616,350	2,108,633	2,080,907	2,371,741	2,633,249	2,766,237
Acquisition	394,844	368,762	374,229	372,385	379,928	405,149	426,743	496,344	480,020	485,102
Treatment:										
Laboratory	31,434	38,493	42,706	41,219	32,315	37,934	39,801	38,381	42,154	46,940
Operating labor	149,426	144,277	152,633	164,778	169,750	180,574	188,150	143,383	167,608	172,754
Chemicals	409,463	367,234	375,132	410,700	411,143	410,172	426,248	423,667	424,586	384,698
Maintenance	170,180	196,119	187,569	216,698	216,442	246,220	223,697	315,748	323,127	334,765
Other	152,710	160,352	175,827	171,299	182,267	166,132	187,145	243,424	282,744	270,910
Total treatment	913,213	906,475	933,867	1,004,694	1,011,917	1,041,032	1,065,041	1,164,603	1,240,219	1,210,067
Power and pumping:										
Operating labor	199,620	202,322	223,715	232,845	228,061	255,809	272,235	239,756	232,280	238,806
Maintenance	182,915	182,814	216,483	226,307	238,245	304,739	252,469	346,596	320,396	309,375
Power	581,588	606,176	613,971	645,362	629,906	696,544	694,359	870,796	902,790	903,397
Other	122,039	124,036	128,545	151,493	150,925	154,805	163,001	181,262	179,479	215,554
Total power and pumping	1,086,162	1,115,348	1,182,714	1,256,007	1,247,137	1,411,897	1,382,064	1,638,410	1,634,945	1,667,132
Transmission and distribution:										
Operating labor	462,986	450,387	475,763	491,722	534,062	570,439	595,005	611,769	607,511	652,791
Maintenance	1,003,220	1,027,617	1,128,650	1,256,074	1,329,452	1,436,244	1,586,635	1,794,415	1,846,084	1,868,514
Other	91,989	75,792	106,959	137,468	64,201	77,331	141,096	80,963	152,840	132,579
Total trans. and distr.	1,558,195	1,553,796	1,711,372	1,885,264	1,927,715	2,084,014	2,322,736	2,487,147	2,606,435	2,653,884
Total operating cost	5,312,156	5,274,884	5,615,223	6,016,945	6,183,047	7,050,725	7,277,491	8,158,245	8,594,868	8,782,422

Table 12 contains the average unit operating costs for each major category based on the number of revenue-producing gallons pumped in a given year. All of the cost categories increased by a factor of less than two, and the total operating cost increased by about 40%.

Table 13 shows each cost category as a percent of total operating cost. Support services accounted for a significant and increasing portion of the utility's budget -- from 25.6% in 1964 to 31.5% in 1973. The other cost categories either decreased or remained constant.

Cincinnati's operating and capital expenses, as defined earlier, are shown on Table 14. Depreciation and interest are defined as the capital expenses for the waterworks system. They remained essentially constant, but operating expenses increased by approximately 65%. The percentage of expenditures allocated to capital decreased from approximately 27% to 22% during the period (Table 15). Operating expenditures are always reported in inflated or current dollars, and capital expenditures are depreciated in historical dollars over a long period of time. The problems related to the depreciation of capital will be discussed later. Since the support services category, which is labor intensive, played an increasingly important role in the cost of water supply, labor and manpower costs will be analyzed in the following section.

LABOR COST ANALYSIS

To evaluate the impact of labor costs on operating costs for water supply, it is necessary to examine the payroll of the water utility (Table 16). Labor costs accounted for 64% of the utility's operating costs in 1964 and for 62% in 1973. The average cost/man-hour increased 71%, and the number of man-hours/mil gal of metered consumption decreased by 23%. The bottom line in the table shows a decreasing capital/labor cost ratio. Although economies of scale were achieved with respect to the number of man-hours used to produce water, the effect on cost was nullified by wage increases. Table 16 therefore illustrates the importance of labor in what is typically presumed to be a capital intensive industry.

DEPRECIATION ANALYSIS

Capital expenditures make up a large portion of the cost of water supply. Depreciation reflects historical costs and not that of replacing a facility based on current costs. Historical costs refer to the original construction cost of a capital facility, and reproduction costs reflect the capital expenditures necessary to build an identical plant today. Historical cost is exact, but reproduction cost is based on the original investment modified by an appropriate index.

The records of the Cincinnati Water Works show the historical value of the plant-in-service to be $111.7 million. The value of pipelines, plant, or equipment previously replaced or fully depreciated is excluded.

TABLE 12. CINCINNATI WATER WORKS UNIT OPERATING COSTS ($/mil gal RPW)

Category	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Support services:										
Administration	$7.36	$7.38	$7.44	$8.65	$8.83	$9.29	$9.68	$10.08	$12.26	$11.84
Accounting and collection	8.82	8.44	8.68	9.50	11.39	11.34	11.38	12.61	14.06	15.37
Service	7.04	7.06	7.28	7.30	7.39	8.36	8.09	9.22	9.78	10.70
Other	19.19	17.36	18.50	18.42	18.94	29.26	26.91	30.29	33.33	34.69
Total support services	42.41	40.24	41.90	43.87	46.55	58.25	56.06	62.20	69.43	72.60
Acquisition	12.31	11.15	11.10	10.90	10.94	11.19	11.50	13.02	12.66	12.73
Treatment:										
Laboratory	.98	1.16	1.27	1.21	.93	1.05	1.07	1.01	1.11	1.23
Operating labor	4.66	4.37	4.53	4.82	4.89	4.99	5.07	3.76	4.42	4.53
Chemicals	12.77	11.11	11.12	12.02	11.84	11.33	11.48	11.11	11.19	10.10
Maintenance	5.31	5.93	5.56	6.34	6.23	6.80	6.03	8.28	8.52	8.78
Other	4.76	4.85	5.21	5.02	5.25	4.59	5.04	6.38	7.46	7.11
Total treatment	28.48	27.42	27.69	29.41	29.14	28.76	28.69	30.54	32.70	31.75
Power and pumping										
Operating labor	6.23	6.12	6.63	6.82	6.57	7.07	7.33	6.29	6.12	6.27
Maintenance	5.70	5.53	6.42	6.63	6.86	8.42	6.80	9.09	8.45	8.12
Power	18.14	18.34	18.21	18.89	18.14	19.24	18.71	22.84	23.80	23.71
Other	3.81	3.75	3.81	4.43	4.35	4.28	4.39	4.75	4.73	5.65
Total power and pumping	33.88	33.74	35.07	36.77	35.92	39.01	37.23	42.97	43.10	43.75
Transmission and distribution:										
Operating labor	14.44	13.63	14.11	14.40	15.38	15.76	16.03	16.04	16.02	17.13
Maintenance	31.29	31.08	33.46	36.77	38.29	39.68	42.75	47.07	48.67	49.04
Other	2.87	2.29	3.17	4.02	1.85	2.13	3.80	2.12	4.03	3.48
Total transmission and distribution	48.60	47.00	50.74	55.19	55.52	57.57	62.58	65.23	68.72	69.65
Total unit operating cost	165.68	159.55	166.50	176.14	178.07	194.78	196.06	213.96	226.61	230.48

TABLE 13. CINCINNATI WATER WORKS OPERATING COST CATEGORIES AS PERCENT OF TOTAL OPERATING COST

Category	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Support services:										
Administration	4.4	4.6	4.5	4.9	4.9	4.8	5.0	4.7	5.4	5.1
Accounting and collection	5.3	5.3	5.2	5.4	6.4	5.8	5.8	5.9	6.2	6.7
Service	4.3	4.4	4.4	4.1	4.2	4.3	4.1	4.3	4.3	4.7
Other	11.6	10.9	11.1	10.5	10.6	15.0	13.7	14.2	14.7	15.0
Total support services	25.6	25.2	25.2	24.9	26.1	29.9	28.6	29.1	30.7	31.5
Acquisition	7.4	7.0	6.7	6.2	6.1	5.8	5.9	6.1	5.6	5.5
Treatment:										
Laboratory	.6	.7	.8	.7	.5	.5	.5	.5	.5	.5
Operating labor	2.8	2.7	2.7	2.7	2.8	2.6	2.6	1.7	1.9	2.0
Chemicals	7.7	7.0	6.7	6.8	6.7	5.8	5.8	5.2	4.9	4.4
Maintenance	3.2	3.7	3.3	3.6	3.5	3.5	3.1	3.9	3.8	3.8
Other	2.9	3.1	3.1	2.9	2.9	2.4	2.6	3.0	3.3	3.1
Total treatment	17.2	17.2	16.6	16.7	16.4	14.8	14.6	14.3	14.4	13.8
Power and pumping:										
Operating labor	3.8	3.8	4.0	3.9	3.7	3.6	3.7	2.9	2.7	2.7
Maintenance	3.4	3.5	3.8	3.8	3.9	4.3	3.5	4.2	3.7	3.5
Power	11.0	11.5	10.9	10.7	10.2	9.9	9.6	10.7	10.5	10.3
Other	2.3	2.3	2.3	2.5	2.4	2.2	2.2	2.2	2.1	2.5
Total power and pumping	20.5	21.1	21.0	20.9	20.2	20.0	19.0	20.0	19.0	19.0
Transmission and distribution:										
Operating labor	8.7	8.6	8.5	8.1	8.6	8.1	8.2	7.5	7.0	7.4
Maintenance	18.9	19.5	20.1	20.9	21.5	20.3	21.8	22.0	21.5	21.3
Other	1.7	1.4	1.9	2.3	1.1	1.1	1.9	1.0	1.8	1.5
Total transmission and distribution	29.3	29.5	30.5	31.3	31.2	29.5	31.9	30.5	30.3	30.2
Total operating expense	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 14. CINCINNATI WATER WORKS CAPITAL AND OPERATING COSTS

Item	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Operating expense	$5,310,156	$5,274,886	$5,615,223	$6,016,945	$6,183,047	$7,050,725	$7,277,491	$8,158,245	$8,594,868	$8,782,422
Capital expense: Depreciation	1,177,441	1,230,236	1,421,671	1,549,928	1,605,070	1,633,727	1,632,017	1,656,520	1,699,258	1,771,299
Interest expense	826,052	947,251	926,933	877,190	887,150	887,103	792,755	802,055	710,555	669,455
Total	7,313,650	7,452,373	7,963,827	8,444,063	8,665,267	9,571,465	9,702,263	10,616,820	11,004,681	11,223,176
Total cost/mil gal	228.10	225.41	236.14	247.19	249.56	264.41	261.39	278.45	290.14	294.54

TABLE 15. CINCINNATI WATER WORKS CAPITAL VERSUS OPERATING EXPENSE RATIOS

Item	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Operating expense ($)	5,310,156	5,274,886	5,615,223	6,016,945	6,183,047	7,050,725	7,277,491	8,158,245	8,594,868	8,782,422
Capital expense ($)	2,033,494	2,177,487	2,348,604	2,427,118	2,492,220	2,520,740	2,424,772	2,458,575	2,409,813	2,440,754
(Interest, $)	(826,052)	(947,251)	(926,933)	(877,190)	(887,150)	(887,013)	(792,755)	(802,055)	(710,555)	(669,955)
Total	7,313,650	4,452,373	7,963,827	8,444,063	8,675,267	9,571,465	9,702,263	10,616,820	11,004,681	11,223,167
Operating expense as % of total	72.61	70.78	70.51	71.25	71.35	73.66	75.01	75.84	78.10	78.25
Capital expense as % of total	27.39	29.22	29.49	28.75	28.65	26.34	24.99	24.16	21.90	21.75

TABLE 16. CINCINNATI WATER WORKS LABOR COST ANALYSIS

Item	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Total payroll ($)	3,393,575	3,399,082	3,664,567	3,946,864	4,085,948	4,446,863	4,467,360	4,979,657	5,261,055	5,474,585
Total hours on payroll	1,110,032	1,116,220	1,102,892	1,120,980	1,148,588	1,141,448	1,115,744	1,094,229	1,071,476	1,046,724
Revenue-producing water ($/mil gal)	32,063	33,061	33,725	34,160	34,722	36,199	37,117	38,128	37,928	38,104
Total payroll metered ($/mil gal)	105.84	102.81	108.66	115.54	117.68	122.84	120.36	130.60	138.71	143.67
Total hours RPW ($/mil gal)	34.62	33.76	32.70	32.81	33.08	31.53	30.06	28.70	28.25	27.47
Average cost/man-hour	3.06	3.04	3.32	3.52	3.56	3.89	4.00	4.55	4.91	5.23
Capital/labor cost ratio	0.60	0.64	0.64	0.61	0.61	0.57	0.54	0.49	0.46	0.45

A reproduction cost was calculated using the historical costs, the Engineering News Record Building Cost Index (1913 = 100) for buildings and equipment, and the Engineering News Record Construction Cost Index (1903 = 100) for pipes and valves. A skilled labor cost factor was used to compute the Building Cost Index, and a common labor cost factor was used to compute the Construction Cost Index. After weighing these capital expenditures with the proper indices, a reproduction cost of $459 million was found for the current plant-in-service, which represents a 311% increase over the historical value. These capital expenditures include capital investment in a new treatment plant (Great Miami), which is expected to be operational soon. Derivation of a reproduction value facilitates examining the impact of inflation on capital cost and the current worth of capital's contribution to output. The computations discussed in this section are summarized in Table 17.

SYSTEM COSTS

With the cost data for the various functional areas discussed earlier, costs were allocated to specific treatment, transmission, storage, and pumping facilities in the system, A general cost was determined for distribution, interest, and overhead. Using costs based on 1973 dollars, and assuming a linear allocation of costs for a given area against capacity required to serve it, the facility costs ($/mil gal) associated with each service area, such as pumping and storage, were established as shown in parentheses in Figure 7.

The costs in the schematic diagram (Figure 7) can be related to the costs in Table 18 and 19. For example, the acquisition cost for water from the Ohio River, including depreciation of the facility and operating costs, is $16.70/mil gal (Figure 7). As a unit of water (mil gal) moves through each facility to another service area, the unit cost of moving it through that area is added to the cost of getting water to that area, thereby creating the incremental costs shown in Table 19. The facility and transmission costs are added to the costs of distribution, interest, and overhead to yield an average unit cost to serve that area. A service zone represents a customer service area and a demand point for water. For purposes of this analysis, an attempt was made to discriminate between the water demanded in a given distribution area and the water transmitted through the area into the next service zone.

PRICING ANALYSIS

The price of water ($/mil gal) for the top 10 users for 1973 in the Cincinnati Water Works service area is shown in Table 20. In the city, the Davison Chemical Company paid a low monthly rate of $87.54/mil gal and a high of $180.26/mil gal. These data are based on utilization of water for 1973, and on the rates shown in Tables 21 and 22.

TABLE 17. CINCINNATI WATER WORKS HISTORICAL AND REPRODUCTION COSTS OF PLANT-IN-SERVICE

Capital facility	Historical cost	Reproduction cost (1973-74 dollars)
Plant	$42,649,160	$146,981,272
Pipe	54,848,943	296,771,626
Misc. plant*	14,202,213	15,237,389
Total	111,700,315	458,990,286

* Capital expenditures that are not specifically identified.

TABLE 18. TRANSMISSION COSTS BETWEEN SERVICE AREAS ($/mil gal)*

From	To A	B1	B2	C1a	C1b	C2	C3a	C3b	C4a	C4b
Treatment plant	$78.14	$75.43	---	$19.76	---	$28.93	$22.29	---	$24.98	---
Service area:										
B1	---	---	$60.26	---	---	---	---	---	---	---
C1a	---	---	---	---	$113.61	---	---	---	---	---
C3a	---	---	---	---	---	---	---	$39.45	---	---
C4a	---	---	---	---	---	---	---	---	---	$50.03

* See Figure 9 for geographic locations of service areas.

TABLE 19. CINCINNATI WATER WORKS COST, CONSUMPTION, AND REVENUE BY AREA, (1973)

Area	Incremental cost ($/mil gal)	Total ($/mil gal)*	RPW (gallons)	Revenue ($)
A	251.19	404.50	190,150	76,915.68
B1	183.55	336.86	629,050	211,901.78
B2	324.29	477.60	339,991	162,379.70
C1a	109.68	262.99	6,796,811	1,787,493.30
C1b	291.58	444.89	290,806	129,376.68
C2	119.49	272.80	9,667,159	2,637,200.90
C3a	122.23	275.54	3,784,174	1,042,691.30
C3b	193.11	346.42	3,873,248	1,341,770.50
C4a	111.25	264.56	7,640,334	2,021,326.70
C4b	226.29	379.60	4,859,095	1,844,512.40
Total	---	---	38,070,818	11,255,568.94

* Includes distribution ($50.52), interest ($17.57), and overhead ($85.22).

TABLE 20. CINCINNATI WATER WORKS WATER COST FOR 10 MAJOR USERS

Major user	High or low month	Month	Units used (mil gal)	Amount billed	Unit charge ($/mil gal)	Location	cost zone
City of Norwood	High	11	163.6	$48,112.24	$294.12	Suburb	C2
	Low	3	112.4	33,046.20	294.12		
Hilton Davis	High	2	56.1	9,464.44	168.83	City	C1a
	Low	1	33.1	5,773.96	174.67		
Sun Chemical	High	9	50.9	8,642.84	169.87	City	C3a
	Low	11	32.0	5,612.72	175.44		
Procter and Gamble	High	7	46.1	14,232.55	308.70	Suburb	C3a
	Low	2	30.6	9,829.27	321.12		
Davison Chemical	High	7	62.3	5,457.40	87.54	City	C2
	Low	12	23.0	4,154.56	180.26		
Metropolitan Sewer	High	12	33.2	5,822.88	175.19	City	C4a
	Low	6	19.6	3,638.88	185.44		
Cincinnati Milacron	High	7	34.8	6.097.44	175.07	city	C2
	Low	4	22.2	4,166.40	187.95		
Kroger Company	High	7	24.0	7.538.95	313.54	Suburb	C1a
	Low	8	16.6	5,447.98	328.26		
Kroger Company	High	7	22.9	4,167.12	181.90	City	C4a
	Low	12	13.2	2,607.72	197.73		
E. Kahn's Sons	High	5	23.3	4,230.68	181.67	city	C4a
	Low	11	14.2	2,778.44	195.17		

TABLE 21. CINCINNATI WATER WORKS METER RATES (APRIL 1, 1969)

Criteria		Minimum charges					
		Inside Cincinnati		Outside Cincinnati in Hamilton and Clermont Counties		Butler and Warren Counties	
Meter size (in)	Family units (number)	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
5/8	1	$2.50	$4.50	$5.00	$9.00	$5.75	$10.35
3/4	2 - 3	2.80	5.40	5.60	10.80	6.45	12.40
1	4 - 5	3.50	7.50	7.00	15.00	8.05	17.25
1½	6 - 12	4.50	10.50	9.00	21.00	10.35	24.15
2	13 - 20	7.00	18.00	14.00	36.00	16.10	41.40
3	21 - 50	9.00	24.00	18.00	48.00	20.70	55.20
4	55 - 115	12.00	33.00	24.00	66.00	27.00	75.00
6	116 - 250	25.00	75.00	50.00	150.00	57.00	170.00
8	over 250	35.00	105.00	70.00	210.00	80.00	240.00
10		40.00	120.00	80.00	240.00	92.00	270.00
12		40.00	120.00	80.00	240.00	92.00	270.00

TABLE 22. CINCINNATI WATER WORKS MONTHLY AND QUARTERLY COMMODITY CHARGES (cents/100 cu ft)

Per month	Per quarter	Inside Cincinnati	Outside Cincinnati in Hamilton and Clermont Counties	Butler and Warren Counties
1,000 - 60,000 cu ft	2,000 - 180,000 cu ft	20	35	40
50,000 - 1 million cu ft	180,000 - 3 million cu ft	16	28	32
Over 1 million cu ft	Over 3 million cu ft	12	21	24

The lowest cost for water delivered to a service area was for area Cla ($262.99/mil gal). Cost areas defined in this report and the 10 major users are shown in Figure 9, which allows for easy visual comparison between the data in Figure 7 and Table 20. These data are summarized in Table 23, which compares the cost and revenues from various levels of water used for the 10 major users in the water works billing area. Many of the major users do not meet the cost of supplying water to them.

Table 23 (column 2) presents a cost comparison based on the assumption that each of the costs in the categories of acquisition, treatment, transmission and distribution, power and pumping, support services, and capital can be based on a cost/mil gal basis. Such an assumption might be questioned, particularly as it relates to support services. An alternate means of cost allocation to the 10 largest users may be generated through adjustment of support services cost/mil gal to overhead cost/customer.

Total support services is $2.8 million, which, when divided by total metered water, gives a unit cost of $72.60/mil gal. The remaining $12.62/mil gal included in the $85.22 support services cost refers to miscellaneous capital and operating expenditures not counted in the incremental costs for each service area.

The $72.60/mil gal cost can be reallocated on a per-customer basis, since there are 186,910 quarterly accounts and 1,533 monthly accounts. Customers billed monthly require three times as many meter readings, yielding a total of 191,509 equivalent quarterly accounts. Support services cost per quarterly customer is therefore $14.44.

For the 10 largest users (which are monthly accounts), the support services cost is $43.32/customer (three times that for the quarterly customers). This adjusted overhead cost is then added to the incremental, interest, adquisition, treatment, distribution, transmission, and miscellaneous support services cost for each zone. Total costs to supply the 10 largest customers are shown in column 3 of table 23.

The adjusted cost approach lowers the costs for the 10 major users, but it raises the proportion of support services that the other users must bear. Nevertheless, the same users that pay less than cost now (column 2, Table 23) would continue to pay less than cost (column 3). Both approaches reveal an interesting picture of costs and the way they vary throughout the Cincinnati Water Works service area.

The average unit costs for all water supplied during the most recent year studied are as follows:

	$/mil gal
Support services	85
Acquisition	17
Treatment	36
Distribution	139
Interest	18
Total	295

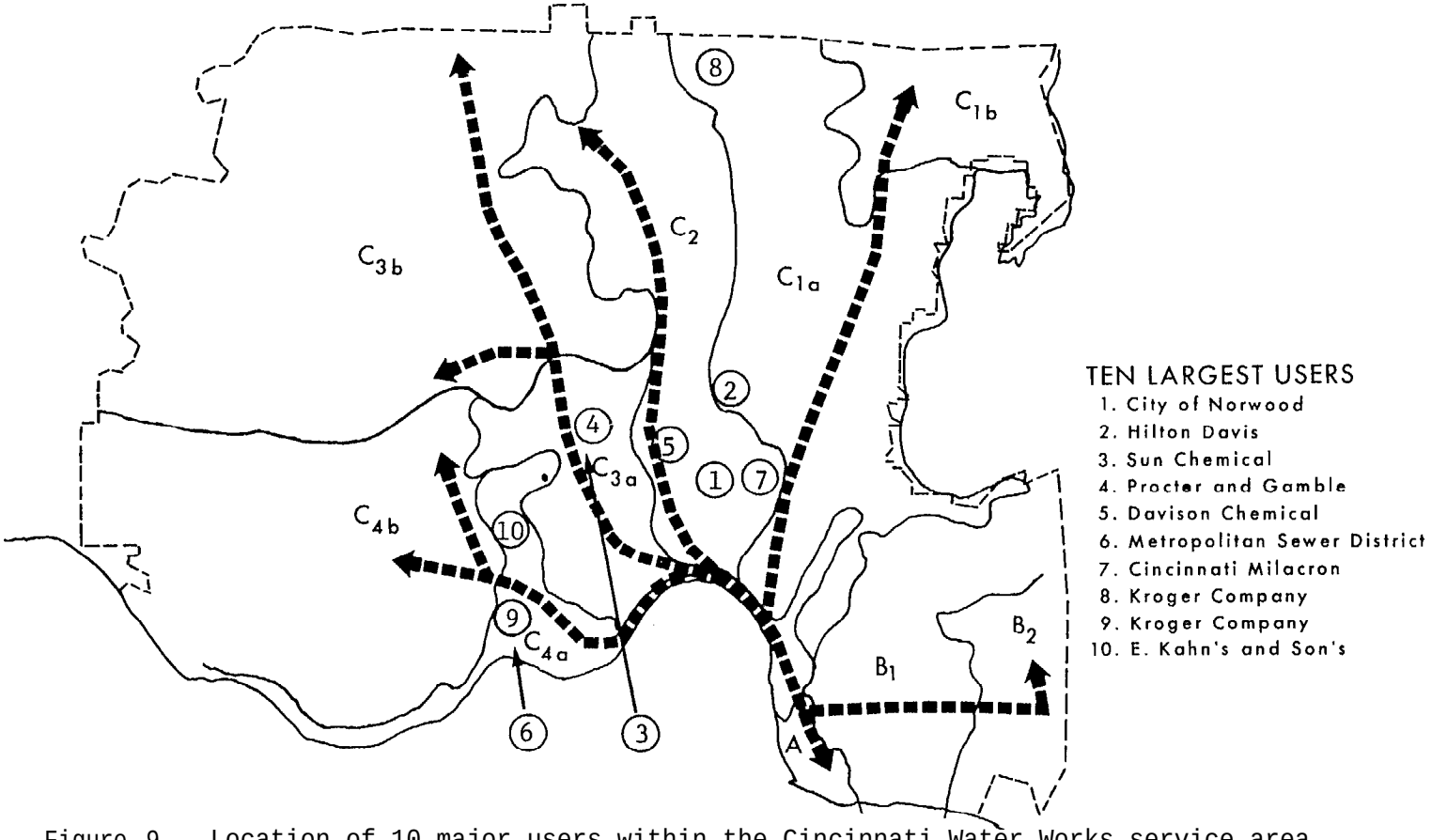

Figure 9. Location of 10 major users within the Cincinnati Water Works service area, B1, B2, Cla, etc. denote various distribution areas within the system.

TABLE 23. ACTUAL PRICE VERSUS COST COMPARISONS FOR TEN MAJOR USERS IN CINCINNATI WATER WORKS SERVICE AREA ($/mil gal)

Major user	Price*	cost+	Adjusted cost+
Norwood	$294.12	$272.80	$243.52
Hilton Davis	168.83 175.67	262.99	233.71
Sun Chemical	169.87 175.44	275.54	246.26
Procter and Gamble‡	308.70 321.12	275.54	246.26
Davison Chemical	87.54 180.26	272.80	243.57
Metropolitan Sewer	175.19 185.44	264.56	235.28
Cincinnati Milacron	175.07 187.95	272.80	243.52
Kroger Company (Suburb)‡	313.54 328.26	262.99	233.71
Kroger Company (City)	181.90 197.73	264.56	235.28
E. Kahn's Sons	181.67 195.17	264.56	235.28

* Wherever two values are presented, one represents the high and the other the low bill in $/mil gal for 1973-74.

+ These values were calculated on an average cost basis and as such do not reflect potential economies of scale that result from having large users in the system.

‡ Suburban users are charged at a higher rate to allow for expansion into Hamilton County.